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EUV Density Diagnostics in Solar and Stellar Spectra

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1. Introduction

Lines emitted by a given ion often show varying degrees of sensitivity to the electron density. Measurements from a spectrometer of two such lines can potentially lead to a determination of the electron density by comparing the observed ratio with the theoretical ratio—such a ratio is termed a *density diagnostic.*

The EUV part of the spectrum is rife with such ratios, and a modern spectrometer, such as that used on the SERTS mission (Thompson et al., 1992), allows these lines to be studied with unprecedented accuracy.

2. Determining the density

When one is presented with several emission lines from a single ion it is possible to use many combinations of ratios to derive densities, often leading to a large spread in results—see figure 6 of Brickhouse et al. (1995), for example. Using one or two selected ratios may give a more accurate answer but ignores the advances made in EUV spectroscopy. Here we present a systematic way of analysing emission lines so as to give confidence in the derived densities. This should be useful in the analysis of existant spectra and those to be obtained by SOHO.

2.1. Criteria

Branching ratios must be checked: Differences between theory and observation may reflect atomic data errors or possible blending. The former is more serious as it affects the density sensitivity of the lines and thus the use of the lines as density diagnostics. If there are no problems the intensities of the lines should be summed and treated as one line.

Choose as many 'good' ratios as possible: A good ratio is one involving two strong, unblended lines close in wavelength (within around 30Å for the EUV), with strong density sensitivity which is suitable for the phenomena being studied (e.g., flare ratios should not be used for quiet sun spectra). Such ratios are identified in density diagnostic papers—Keenan (1995) provides excellent references for all the coronal ions.

2.2. Consistency

With this benchmark density (or densities) one must look to see that the other, unused lines are in agreement. Often this is not the case, and one must look for reasons why.

Examine other spectra: Some ratios consistently give anomalous results, and analysis of previous solar spectra will reveal this. Thomas & Neupert (1994) give references to other catalogues.

Instrument calibration: Ratios involving lines far apart in wavelength are subject to potential errors in the calibration of the instrument. As a check of the calibration, density *insensitive* ratios should be used.

After an ion has been fully assessed, the results need to be compared to those from other ions.

2.3. Example: Fe XIV lines in the SERTS-89 spectrum

Twelve doublet–doublet transitions of Fe XIV were identified in the SERTS-89 catalogue (Thomas & Neupert, 1994), five of which are related to others by branching ratios and one of these is inconsistent with theory (the results of Brickhouse et al. (1995) are used here), namely the 257/270 ratio, hence we flag these lines as being potentially awry.

We further identify 3 'good' ratios as 219/(211+220), (252+264)/(274+289) and 353/(334+356), 2 of which give densities of 9.4 and 9.7, while (252+264)/(274+289) gives a density of ≤ 8.

211/274 and 274/334 are density insensitive ratios, with theoretical values of around 2.8 and 1.6, of which only the latter is consistent with the observations.

Hence we conclude that there seems to be two distinct groups of Fe XIV lines: the < 274 and ≥ 274 lines, which are internally consistent, but discrepant with each other. This problem would appear to be due to atomic physics as opposed to calibration problems due to the proximity of the 264 and 274 lines.

The derived density of between 9.4 and 9.7 is consistent with values obtained for Fe XIII and S XII.

3. EUVE spectra of Procyon and α Centauri

EUV spectra of stars other than the Sun have become available only recently with the advent of the EUVE mission. This has spectral resolution akin to early solar spectra and so line blending makes density diagnostic analysis difficult.

For the strong Fe X–XIV ratios, however, densities can be obtained. The most recent EUVE observations of the quiet, solar-type stars α Cen and Procyon yield densites in the region $9.0 \leq logN_e \leq 9.5$.

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